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An Analysis of Post-Mining Water Balance Adjustments for Three Surface Mining Scenarios, Westmoreland Resources Absaloka Mine, Montana

Technical Support Document
for the Absaloka Mine FES

Submitted to:
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Helena, Montana

September 20, 1984

I. INTRODUCTION

Westmoreland Resources (WR) has operated the Absaloka Mine in southern Big Horn County, Montana, since 1972. The Absaloka Mine extracts coal by surface methods for shipment to out-of-state utilities. The mine is permitted under Montana and federal laws and expects to continue operations for about the next three decades. Coal production currently approximates four million tons per year (DES, 1984, p. I-1). The mine is already permitted to increase production up to ten million tons per year if and when market conditions allow.

Westmoreland Resources, under current Montana law, has submitted a proposed mining and reclamation plan for an additional 629 acres beyond that which is currently permitted. In accordance with applicable state and federal laws, a draft environmental impact statement (DES) was prepared by Montana Department of State Lands (DSL) and the U.S. Office of Surface Mining (OSM). The DES was released for public comment in May, 1984.

Comments received by DSL on the DES identified concerns related to changes in the hydrologic balance of North Coulee due to mining under the proposed plan. Also, recommendations were made concerning alternative mining scenarios which might minimize hydrologic impacts on North Coulee.

In response to these comments, DSL, Westmoreland Resources, and Stiller and Associates, consultant to DSL for the EIS, developed several mining scenarios which reasonably address identified concerns.

Based upon these scenarios, Stiller and Associates was requested to evaluate the general water balance changes which might occur under each scenario. This report summarizes the results of the investigation completed by Stiller and Associates.

II. OBJECTIVES OF THE INVESTIGATION

Public comments on the DES (DSL and OSM, 1984) raised questions and issues which cannot be answered by reference to Westmoreland Resources' permit application, or analyses completed by DSL or its consultant. Therefore, the objective of this investigation is to analyze and predict general changes in the hydrologic balance of North Coulee which might be expected under several different mining alternatives. Each alternative is ~~should likewise be~~ compared with North Coulee's pre-mining hydrologic situation. Because mining in North Coulee's upper watershed has already been permitted, and mining is currently in progress there, it is deemed more expedient and appropriate to compare mining's ultimate impacts with the pre-mining hydrologic environment. -befor mining crossed the divide??

?? what does this mean

alternatives should be compared with hydrologic conditions as it is affected by current mining.

III. PREVIOUS WATER BALANCE INVESTIGATIONS

North Coulee's hydrologic environment has been the subject of investigations for more than a decade. Westmoreland Resources initiated studies in the area with work by its consultants, Dames and Moore, and by Montana Bureau of Mines and Geology. Results of these studies are reported by Westmoreland Resources in its permit application (1982, Book I).

More intensive studies of North Coulee and its springs were undertaken in 1979 during DSL's most recent permitting episode. These studies (e.g. Stiller, 1979; Hydrometrics, 1979; Envirosphere, 1979; Leaf, 1979) primarily addressed impacts to specific springs which occur in and adjacent to North Coulee. Leaf (1979) is apparently the only investigator from that period whose work is based upon water balance methods.

Leaf (1979) examined the impact to individual springs and subwatersheds to be expected under the last WR mining plan, approved by DSL in 1980. Analyses are based upon water balance calculations for each spring's watershed and assume the influence of actual evapotranspiration to be the primary utilizer of precipitation input to the watersheds. The equation used (Leaf, 1979, p.18) ignores ground water discharges and interception losses as significant components of the system's consumptive uses; however, the conclusions appear reasonable for the level of analysis undertaken. Leaf (1979,

Table 2) concluded that even with the conservative assumption of total loss of water inputs to subwatersheds affected by mining, there would still be excess water yields (i.e. spring discharges) following mining.

The present permit application contains an analysis of potential water balance changes which would occur as a result of mining under the proposed plan. The analysis was prepared by Westmoreland Resources' consultant, Hydrometrics (WR permit application, 1982, Book I, Exhibit I-33).

The water balance analysis completed by Hydrometrics emphasizes surface runoff and ground water discharge as the major consumptive components of interest in North Coulee. Interception is not addressed, and evapotranspiration is disregarded on the basis of imprecision in any values which might be used. Hydrometrics concludes (WR permit application, Book I, Exhibit I-33, pp. 6-28 thru 6-32) that total surface and ground water discharges from North Coulee after mining may range from zero to as much as 50 percent, depending upon how much a decrease is compensated for by changes in total evapotranspiration demands of coulee-bottom vegetation between the mined area and North Coulee's confluence with East Fork Sarpy Creek.

Elsewhere in the permit application (Book I, Exhibit I-33, pp 5-1 thru 5-8), Hydrometrics provides an approximation of the hydrologic cycle indicating that precipitation inputs to the North Coulee drainage are almost equalled by evapotranspiration losses from the

watershed and that surface runoff and ground water discharges are lesser components of the system. This is to be expected in a locally recharged, semiarid basin like North Coulee.

IV. STUDY DESIGN

A. Water Balance Equation

The present analysis uses a standard equation to assess changes in the North Coulee water balance under a variety of proposed and assumed mining scenarios. As presented by Dunne and Leopold (1978, p. 237), the equation takes the form:

$$P = I + AET + R + GWF + dSM + dGWS \quad (1)$$

where:
- P = Precipitation input to the basin
- I = Interception
- AET = Actual evapotranspiration
- R = Runoff from the basin
- GWF = Ground water discharges from the basin
- dSM = Changes in soil moisture
- dGWS = Changes in ground water storage

Equation 1 is appropriate to the present case because the locally recharged ground water basin closely approximates the North Coulee surface water basin. Equation 1 can be simplified by assuming that changes in soil moisture and ground water storage are irrelevant over the long term. The comparison of pre-mining conditions with assumed or calculated post-mining equilibrium conditions is very likely separated by tens or hundreds of years. Over such a time span, changes in soil moisture and ground water storage are not important. Therefore, for the present purpose, the important variables in Equation 1 are: interception, actual evapotranspiration, runoff, and ground water discharge. These variables will fluctuate both seasonally

and annually, partially in response to variations in system input, precipitation. Control of precipitation is not likely, however; man's primary means of affecting the balance of the equation or changes in the variables is by altering land use.

Analysis of the hydrologic balance under each mining scenario is accomplished in the present study by comparing and contrasting changes within the right side of Equation 1 caused by human alterations of North Coulee. Although of a gross nature, such comparisions allow an approximation of changes which might occur under various land use alternatives.

B. Land Use Scenarios

Four land use or mining alternatives in North Coulee are evaluated for the present study. These scenarios are defined below:

A. Pre-mining conditions;
B. WR proposed mine plan;
C. Limited mining to only areas where double-seam coal extraction can occur, avoiding most of upper North Coulee, and,
D. Limited mining determined on the basis of maintaining and assuring the permanence and distribution of water sources in upper North Coulee.

Scenario A, pre-mining conditions, assumes that North Coulee has not been disturbed by mining. In fact, however, DSL granted WR permission to generally affect North Coulee in both prior permits, numbers 78005 and 80005. Area under permit 78005 was not originally part of the North Coulee watershed, but because of the mining process

and direction, mining in permit area 80005 will move the North Coulee drainage divide to the west and south, thereby enlarging the upper North Coulee watershed area. The result of this is that the pre-mining North Coulee draiange area is smaller than for any alternative involving mining. Scenario A also provides a basis for comparision of mining alternatives to quasi-natural conditions. Figure 1 generally shows the pre-mining upper North Coulee drainage.

Scenario B is an evaluation of the North Coulee water balance following completion of WR proposed mining and reclamation plan. Changes in the right side of Equation 1 are calculated for only that portion of North Coulee above the county road, because no direct mining disturbance will occur lower in the coulee. Mining disturbance limits under Scenario B are shown on Figure 2.

Scenario C assumes that DSL will eventually approve a WR proposal to mine only that portion of the North Coulee watershed underlain by both seams of recoverable coal, the Rosebud-McKay and Robinson coal seams. Because the upper reach of North Coulee is eroded through the Rosebud-McKay coal seam, much of the partial burn areas (clinker) and alluvium and colluvium within the coulee would remain undisturbed. This will retain some of the hydrologic integrity of the coulee's combined ground and surface water system. Approximate mining disturbance limits are shown on Figure 3 and were provided by WR.

The primary determining criterion behind Scenario D is to maintain the hydrologic integrity of upper North Coulee such that mining will not affect the permanence or distribution of springs in the coulee. Therefore, the limit of mining disturbance is even more restrictive than for Scenarios B or C. These limits are shown on Figure 4.

Each of the four scenarios is evaluated in two locations: at the mouth of North Coulee where it joins East Fork Sarpy Creek; and at the county road, just below where mining is proposed in the coulee's upper reaches. In such a manner, hydrologic changes are reviewed both for "site specific" impacts, as well as in the context of the East Fork Sarpy Creek watershed. For purposes of identifying the four scenarios and their two geographic situations in this report, an alphanumeric designation is given for each, as shown below.

TABLE 1. LAND USE ALTERNATIVE ALPHANUMERIC DESIGNATIONS

	North Coulee Limit	
Scenario	All North Coulee	North Coulee at County Road
A. Pre-mining conditions	A1	A2
B. WR's proposed mine plan	B1	B2
C. Mining limited to double-seam extraction	C1	C2
D. Mining limited to maintain hydrologic integrity	D1	D2

V. DATA INPUTS FOR WATER BALANCE EQUATION

Components of the water balance equation described in Chapter IV are evaluated specifically as applied to the North Coulee drainage. These components include; precipitation (P), ground water flow (GWF), runoff (R), interception (I), and evapotranspiration (ET). Determinations of values for these parameters are based on data collected by WR, information contained in the scientific literature, and/or by direct analysis of the various mining alternatives.

A. Precipitation

Analysis of both long - and short-term data from meteorological recording stations in the vicinity of North Coulee indicates little variability exists between stations relative to average annual precipitation. Precipitation records for Hysham, located approximately 35 miles north of the mine area, indicate annual precipitation ranges from less than six inches to greater than 20 inches, with an average of approximately 13 inches for the 1946-1983 period of record (NOAA, 1984). Annual precipitation records for Colstrip, located approximately 23 miles east of the application area, show a similar range in annual precipitation values for the same period of record, with an average of about 15 inches (NOAA, 1984). Statistical analysis of these data indicate that there is no significant trend in annual precipitation values over the last 30 years.

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Two precipitation recording stations are operated by WR: one is located at the mine office and one is located in the mine area. Based on eight years of record at the mine office station (1976-1983), average annual precipitation is 14.8 inches, with extremes of 8.7 inches and 24.2 inches. Based on records for 1976-1981, average annual precipitation at the mine site station is 14.0 inches, with a range in values of 12.6 inches to 24.2 inches (WR permit application, Book F, Volumes 1-3).

Because the average annual precipitation value at the mine site station is within the range of average annual values at other stations with longer periods of record, and because this station is probably more representative of the micro-climate of the application area, the value of 14.0 inches is utilized in this analysis as being representative of mean annual precipitation conditions in North Coulee.

B. Ground Water Flow

Several aquifer systems contribute ground water to the East Fork Sarpy Creek hydrologic system through North Coulee. These aquifers include: alluvial/unconsolidated material deposits which underlie the coulee bottoms, and bedrock units consisting of the Rosebud-McKay coal (R1) and overburden unit which overlies the R1. For purposes of this analysis of the North Coulee ground water system, an evaluation is also completed for a spoils aquifer, the occurrence and extent of which are subject to the mining alternatives described in Chapter IV.

Ground water flow through the spoils aquifer is contingent upon estimated hydraulic properties and equilibrium flow configuration. Because pre-mine ground water flow in North Coulee is recharged locally, it is assumed post-mine ground water flow will be recharged similarly. Changes in ground water head in the spoils aquifer as compared to pre-mine conditions are considered insignificant owing to the locally recharged nature of the area. It is assumed, then, that the most significant factor in comparing pre- to post-mining ground water flow is the hydraulic properties of the medium through which the ground water flows.

1. Alluvium/Unconsolidated Materials

Hydrogeologic characteristics of the alluvium/unconsolidated material aquifer are categorized geographically to account for the various mining alternatives described in Chapter IV. Ground water flow in the alluvial system is calculated at two locales in the North Coulee drainage: near the drainage's confluence with East Fork Sarpy Creek, and at the county road (Figure 1). Values utilized in calculating ground water flow in North Coulee alluvium near its confluence with East Fork Sarpy Creek are those detailed in the permit application (Book I, Exhibit I-31, p. 21). Total alluvial ground water flow at this locale (Table 2) is based on aquifer tests of the aquifer, surveyed ground water gradients, and cross-sectional dimensions of the alluvial aquifer.

Alluvial ground water flow at the county road (Table 2) is calculated using dimensions of the geologic cross-section for Dam 20 (WR permit application, Exhibit I-33, Figure 19), and hydraulic characteristics of observation well AC-23 (Book I, Exhibit I-33, Appendix 3). Observation well AC-23 is used as being representative of alluvium at the county road owing to its similarity to the clinker gravel type lithology present in this area.

Utilizing the Dam 20 cross-section, the average width of alluvium at the county road is approximately 50 feet. It is assumed that the ground water gradient in the alluvium at this site is similar to that near the mouth of North Coulee, or 0.0077 ft/ft. Transmissivity of the alluvium is assumed to be similar to that calculated from aquifer tests conducted on observation well AC-23, or 5000 gpd/ft. Utilizing these inputs to the Darcy equation, total alluvial ground water flow at the county road is approximately 2.2 AF/yr. (Table 2).

2. Overburden

Ground water flow characteristics of the overburden aquifer in North Coulee are obtained from analyses described in the permit application (Book I, Exhibit I-33). It is assumed that because the overburden in North Coulee discharges directly the coulees dissecting the unit, all contribution of overburden ground water from North Coulee to the East Fork Sarpy Creek hydrologic system can be measured in the alluvial unit at the mouth of North Coulee. For this reason, calculations of ground water flow are completed only for the overburden unit at the county road.

In quantifying overburden ground water flow at the county road, a flow net analysis was completed between the 3540 and 3550 equipotential lines from Westmoreland's application (Plate 3, Exhibit I-31). Aquifer lengths and gradients derived from this analysis, in conjunction with average transmissivity values obtained from aquifer tests conducted on overburden wells in the area (Volume 11, Exhibit I-33, Appendix 3), were used to compute the total overburden ground water flow of 2.1 AF/yr. at the county road. Inputs to the Darcy equation used in this flow assessment are shown on Table 2.

3. Rosebud-Mckay (R1) Coal

An approach similar to that described for the overburden aquifer is used to evaluate ground water flow in the Rosebud-McKay (R1) coal seam in North Coulee. As with the overburden aquifer, it is assumed that the R1's ground water contribution to East Fork Sarpy Creek hydrologic system is a component of the North Coulee alluvial system owing to the dissection of the aquifer in the area by coulees containing the alluvial unit.

Ground water flow in the R1 at the county road is calculated by a flow net analysis between the 3450 and 3460 equipotential lines from the permit application (Exhibit I-31, Plate 4). The length and gradient of the aquifer was obtained from this analysis, and, in conjunction with average transmissivity values obtained from aquifer tests conducted on R1 observation wells in the area (Exhibit I-33, Appendix 3), were used to calculate total ground water flow in the R1

at the county road. Components of the Darcy equation used in the assessment of R1 ground water flow are detailed in Table 2.

4. Spoils

Ground water flow through spoils material in reclaimed mined areas is difficult to evaluate owing to the heterogeneity of the material and the lack of data describing equilibrium conditions in the medium. Hence, several assumptions are necessary to quantity spoils contribution to North Coulee ground water flow.

It is assumed that the spoils ground water flow configuration and gradient will be similar to that of the overburden aquifer in its pre-mine state. As well, it is assumed that the total contribution of spoils ground water to the East Fork Sarpy Creek hydrologic system upon attaining equilibrium will include an input from the spoils to the Robinson (R2) coal, which subcrops to the East Fork alluvium in the area, and/or to the undisturbed alluvial aquifer present in undisturbed coulee bottoms.

Permeability values for spoils aquifers in the Powder River Basin have been described by Rahn (1976, 1980) and Montana Bureau of Mines and Geology (unpublished data). These values range from four to 21 gpd/ft^2. Overburden permeability in the North Coulee area is near the lower end of this range, and, as such, it is assumed that corresponding transmissivity values for the overburden should be representative of spoils transmissivity if a similar saturated thickness of the spoils medium is present.

Based on an average overburden transmissivity calculates from wells tested in the vicinity of North Coulee (Exhibit I-33, Appendix 3), an equilibrium transmissivity value of 25 gpd/ft is expected for the spoils aquifer. The length of the spoils aquifer normal to equilibrium flow direction varies depending on the different mining alternatives (Chapter IV). Therefore, total ground water flow through the spoils aquifer is premised on mine configuration and, as such, is calculated for each mining alternative (Table 2).

C. Runoff

The runoff (R) component of the water balance equation (Chapter IV) for North Coulee is calculated for two distinct land types: undisturbed areas, which reflect natural conditions; and reclaimed areas of lands disturbed by mining. Justification is provided below for a unit runoff rate for each identified land types.

1. Undisturbed Land

A unit runoff rate for lands not disturbed by mining in North Coulee is established utilizing site specific data and data from the entire Sarpy Creek basin as measured at Hysham. Based on analysis of runoff data for Sarpy Creek at Hysham, average annual runoff for the total Sarpy Creek drainage is 3020 AF (Stiller and Associates, 1984,

Figure 2 and Table 1). Total drainage area of Sarpy Creek at Hysham is 453 $mi.^2$ or 289,920 acres (USGS, 1983). The average unit runoff rate for the Sarpy Creek basin is, thus, approximately 0.01 AF/acre/year.

Utilizing 1982 runoff data provided by Hydrometrics (1983), approximately 6.2 AF of runoff was recorded in North Coulee at gaging station G-7, located near the county road. Because 1982 was a near-average year in terms of annual precipitation, it is assumed that 1982 annual runoff is representative of average conditions in North Coulee. Drainage area above gaging station G-7 is approximately 720 acres; therefore, unit runoff for North Coulee, based on this analysis, is 0.009 AF/acre/year.

The unit runoffs calculated by both methods are similar, and, as such, the value of 0.01 AF/acre/year for undisturbed lands is used in this analysis.

2. Reclaimed Land

Unit runoff values for reclaimed lands in North Coulee are based on data contained in the permit application (Exhibit I-33, Chapter 6) and in Stiller and Associates (1984). Runoff data from reclaimed areas in East Coulee (located adjacent to North Coulee) indicates a unit runoff rate in 1982 of 0.02 AF/acre/year. The gaging station is located below unmined topography and provides a direct correlation to

what conditions are expected to be at North Coulee. As discussed previously, 1982 was a near-average precipitation year, and thus, annual runoff is expected to be similar to 1982 conditions.

In its evaluation of available runoff from reclaimed topography for Pond 20 on the North Coulee drainage, Stiller and Associates (1984) calculated an average annual runoff of 15 AF to this site. The unit runoff rate to Pond 20, based on a drainage area of 752 acres, is 0.02 AF/acre/year. Because of the similarity of these derived values, a unit runoff rate of 0.02 AF/acre/year is used for reclaimed lands in this analyses.

D. Interception

Interception rates (I) of precipitation by vegetation are characterized for three general vegetative types; forest, grasslands, and riparian. Although interception is probably the most difficult of the components of the water balance equation to quantify, it is a significant factor in areas in which vegetation is altered (Dunne and Leopold, 1978). Such is the case in mined areas where reclamation efforts result in varying revegetation practices.

1. Forest

Median canopy interception for coniferous forest is 28% of gross precipitation (Dunne and Leopold, 1978). This figure is based on numerous observations of interception of both rain and snow. The value is considered conservative for forests of this type in North America.

Utilizing the average annual precipitation value of 14.0 inches described previously, the unit interception rate for forested lands in North Coulee is approximately 0.33 AF/acre/year. This value is assumed applicable to both native forests and lands revegetated with coniferous vegetation.

2. Grasslands

Interception rates for grasslands are based on several assumptions regarding physical characteristics of existing and revegetated grasslands. These characteristics of grass include shape, height, and density. By factoring these characteristics into appropriate equations, interception for grasslands in the North Coulee area can be quantified.

It is assumed that the physical characteristics of post-mine grasslands will be similar to pre-mine conditions upon successful revegetation and when equlibrium conditions persist. The dominant grass type is assumed to be similar to brome, and accordingly, an interception equation described by Crouse and others (1966) is applicable. This equation shows that annual interception rates are related to vegetation by the following relationship:

$$I(mm) = 0.86\ HV$$

where: H = average grass height (mm)
and: V = cover density (decimal fraction)

Average height of brome-type grasses in the North Coulee area is approximately 20 cm (S. McCoullough, personal communication). Cover density is calculated as a weighted average of silty and sandy vegetation subtypes in North Coulee, as described in the permit application (Book H, Exhibit H-12). Utilizing this approach, the average grassland cover density in North Coulee is 0.31.

Solving the interception equation and coverting to constant units results in an average annual interception rate of 2.1 inches, or approximately 15 per cent of average annual precipitation. This value compares well with interception rates reported for brome-type grasslands in the scientific literature. Utilizing the average annual precipitation value of 14.0 inches for North Coulee, the annual unit interception rate for grasslands in North Coulee is 0.18 AF/acre/year.

3. Riparian

It is assumed that interception characteristics of riparian vegetation are similar to those of deciduous forest, as described by Dunne and Leopold (1978). Median canopy interception for deciduous vegetation is approximately 13 per cent (Dunne and Leopold, 1978, Table 3-1). Assuming an average annual precipitation of 14.0 inches, the mean annual unit interception rate for riparian vegetation in North Coulee is about 0.15 AF/acre/year.

E. Evapotranspiration

Evapotranspiration (ET) rates in North Coulee are based on the three vegetation types described above: forest, grasslands, and riparian. Evapotranspiration rates are obtained from the permit application (Book I, Exhibit I-33, Chapter 5). These which appear to be reasonable approximations of conditions at North Coulee.

The following are average unit ET rates utilized in this analysis for vegetation types in North Coulee: forest, 1.23 AF/acre/year; grasslands, 1.18 AF/acre/year; and riparian, 2.83 AF/acre/year. It is assumed that mean annual rates are comparable for each vegetation type in both pre- and post-mining scenarios.

TABLE 2. SUMMARY OF GROUND WATER FLOW DATA: NORTH COULEE

Aquifer	Transmissivity (gpd/ft)	Gradient(3) (ft/ft)	Aquifer Width (ft)	Discharge AF/yr
Alluvium (1)	9150(3)	0.0077	160	12.6
Alluvium (2)	5000	0.0077	50	2.2
Overburden (2)	13	0.0235	6240	2.1
Rosebud-McKay (2)	11	0.0160	4930	1.0
Spoils	25	0.0235	(4)	(4)

(1) Entire North Coulee
(2) At County Road
(3) Average of flow tube components in flow net analysis.
(4) Variable, depending on mining alternative

TABLE 3. PREDICTED WATER BALANCE INPUTS AND OUTPUTS IN NORTH COULEE FOR BASELINE CONDITIONS AND THREE MINING ALTERNATIVES.[1]

Scenario	Acres	Precipitation Input[2]	GWF[3]	% of Sum	R[4]	% of Sum	I[5]	% of Sum	AET[6]	% of Sum	Sum of Outputs[7]
ALL NORTH COULEE											
A1	1647	1922	12.6	0.5	16.5	0.7	375	15.4	2026	83.4	2430
B1	1791	2090	13.4	0.5	9.3	0.4	384	14.8	2194	84.3	2601
C1	1791	2090	13.4	0.5	24.0	0.9	388	14.8	2193	83.8	2618
D1	1791	2090	13.4	0.5	22.9	0.9	391	14.9	2193	83.7	2620
NORTH COULEE ABOVE COUNTY ROAD											
A2	720	840	5.3	0.5	7.2	0.7	166	15.6	886	83.2	1065
B2	864	1008	6.1	0.5	0	0	175	14.1	1057	85.4	1238
C2	864	1008	6.1	0.5	14.7	1.2	179	14.3	1053	84.0	1253
D2	864	1008	6.1	0.5	13.6	1.1	182	14.5	1054	83.9	1258

1. Land use alternatives and scenario designations described in Chapter IV.
2. Based on 14.0 inches per year; values in acre feet per year.
3. Ground water flow, in acre feet per year.
4. Runoff, in acre feet per year.
5. Interception losses, in acre feet per year.
6. Actual evapotranspiration losses, in acre feet per year.
7. Acre feet per year.

VI. DISCUSSION

Results of the calculations completed with Equation 1 for the four land use alternatives described in Chapter IV are shown in Table 3. The fact that the two sides of the water balance equation for North Coulee do not equate does not preclude use of the equation for evaluating relative differences in outputs on the equation's right side under various scenarios. Effects of various mining alternatives on the North Coulee water budget are thus quantified such that the general impacts of such actions are identified.

A. Entire North Coulee

Analysis of the water budget for the entire North Coulee drainage under the various mining alternatives is premised on drainage areas and unit values of above-ground components of the water balance equation and on mine configuration and appropriate hydraulic parameters for subsurface components of the equation. The North Coulee drainage area is 1647 acres in the pre-mine state, but the drainage area of the coulee is expanded to 1791 acres by mining. This increase in drainage area affects outputs of Equation 1 for Scenarios B1, C1, and D1.

The establishment of permanent impoundments (Ponds 19 and 20) in North Coulee under Scenario B1 significantly affects outputs for the water balance equation under this alternative. Because of their design, the impoundments act to collect all runoff, artificially

recharge the downgradient alluvial aquifer, and cause evaporation from the pond's surfaces. These phenomena are factored into the analysis of Scenario B1.

1. Ground Water Flow

Outputs of ground water flow from North Coulee to the East Fork Sarpy Creek hydrological system for the various scenarios described in Chapter IV are shown in Table 3. As discussed in Chapter V, total pre-mine ground water flow from all aquifers in North Coulee (Scenario A1) is assumed to be reflected in the North Coulee alluvial aquifer discharge near the mouth of the drainage. The calculated value of 12.6 AF/year for Scenario A1 (Table 3) represents baseline ground water discharge from North Coulee.

Impacts to the ground water flow system in North Coulee under Scenario B1 include proposed permanent impoundments in the drainage and the replacement of contributing aquifers in the upper reaches of North Coulee with spoils material. Seepage from proposed permanent impoundments (Pond 19 and 20) is calculated utilizing design seepage rates and the length of time the ponds will contain water annually (Stiller and Associates, 1984), in addition to determinations of maximum flow capacity of the downgradient alluvium below the two ponds. Assuming water is present in the ponds an average of eight months per year, total annual seepage loss to the alluvial aquifer from the permanent impoundments is approximately 2.2 AF (Table 3).

Ground water flow through the spoils aquifer under Scenario B1 is based on assumptions outlined in Chapter V, and an assumed aquifer width of approximately 6000 feet. Utilizing these data, total annual ground water flow in the spoils under scenario B1 is 3.9 AF. Ground water flow in North Coulee aquifers not subject to mining disturbances is assumed to be the difference between the total flow from North Coulee under Scenario A1 and ground water flow values calculated for the aquifers at the county road (See Scenario A2). Based on this assumption, ground water flow from undisturbed aquifers in North Coulee under Scenario B1 is 7.3 AF/year. Summing all components of ground water flow from North Coulee under Scenario B1 results in a total of 13.4 AF/year (Table 3).

Ground water flow in Scenario B1 is slightly greater than pre-mine conditions (Scenario A1), owing primarily to artificial recharge to the system provided by construction of proposed permanent impoundments near the lower end of mining disturbance. Recharge from the impoundments appears to more than offset the net loss of flow due to spoils emplacment in areas occupied by pre-mine aquifers.

Ground water flow in Scenario C1 is subject to disturbance according to the mine plan described in Chapter IV. Foremost of the mining-related impacts is the replacement of contributing aquifers in the mine area with spoils material. Ground water flow through the spoils aquifer under Scenario C1 is based on assumptions described in

Chapter V and an assumed aquifer width of 4900 feet. Using these figures, total annual ground water flow through the spoils in North Coulee under Scenario C1 is 3.2 AF.

Because the coulee bottom alluvial aquifer is not disturbed in Scenario C1, the annual contribution of alluvial ground water flow (2.2 AF) at the county road will be unaffected. Ground water flow from the remainder of the unaffected North Coulee aquifers below the county road is the same as that described for Scenario B1, or 7.3 AF/year. Unaffected aquifers above the county road contribute an additional 0.7 AF/year. Thus, total ground water flow in North Coulee under Scenario C1 is the sum of the four components described above or 13.4 AF/year (Table 3).

Ground water flow under Scenario C1 is also slightly greater than baseline conditions (Scenario A1). This apparent increase is due to the likelihood that the spoils may be more transmissive than the existing bedrock aquifer in upper North Coulee.

Ground water flow in Scenario D1 is impacted by mining activity in the upper reaches of North Coulee where spoils replace bedrock containing contributing aquifers. Ground water flow through the spoils aquifer in Scenario D1 is based on assumptions outlined previously (Chapter V) and an assumed aquifer width of 4900 feet. Based on these figures, annual ground water flow in the spoils is approximately 3.2 AF.

As in Scenario C1, the alluvial aquifer above the county road is unaffected under Scenario D1. Ground water flow from this source is 2.2 AF/year. The remaining undisturbed aquifer systems in North Coulee below the county road produce flow similar to that described for Scenario B1, or 7.3 AF/year. An additional 0.7 AF/year is contributed by unaffected aquifers above the county road. Totaling all ground water components to North Coulee under Scenario D1 results in an annual flow of 13.4 AF (Table 3). Ground water flow under Scenario D1 is also slightly greater than that for baseline conditions (Scenario A1), and would be comparable to that for Scenarios B1 and C1 (Table 3).

2. Runoff

Surface runoff volumes from the entire North Coulee drainage to East Fork Sarpy Creek for the various scenarios are shown in Table 3. As discussed in Chapter V, runoff rates are based on a unit basis for both disturbed and undisturbed lands. Total runoff for each scenario, therefore, is calculated by summing the product of runoff rates and drainage areas for disturbed and undisturbed lands.

Baseline conditions under Scenario A1 assume that none of the 1647 acres in North Coulee is disturbed by mining activity. Multiplying the total undisturbed acreage by the appropriate unit runoff yields a total annual runoff of 16.5 AF (Table 3).

Runoff for Scenario B1 is calculated similarily to Scenario A1 except acreages of disturbed and undisturbed lands are adjusted to account for mine plans identified in the current application area and in permit no. 80005 areas. Analysis of this scenario indicates that 864 acres are disturbed by mining and 927 acres remain undisturbed. Multiplying by appropriate unit runoff rates yields a volume of 26.6 AF. Because of the construction of permanent impoundments near the county road, however, a total of 17.3 AF/year of potential runoff to East Fork Sarpy Creek is contained, resulting in a net runoff delivery to East Fork of 9.3 AF/year.

Although the volume of runoff that enters East Fork from Sarpy Creek from North Coulee under Scenario B1 is reduced substantially as compared to baseline conditions (Scenario A1) because of the impoundments, the impact of such a scenario is decreased somewhat owing to ground water recharge to alluvium through pond seepage. As well, the impounded runoff will provide for the maintenance of a riparian vegetation community.

Runoff from North Coulee under Scenario C1 will also be dependent on land disturbance factors. Disturbed lands constitute 605 acres of the North Coulee drainage in Scenario C1, while undisturbed lands include 1186 acres. Resultant runoff to East Fork Sarpy Creek is 24 AF/year (Table 3). This value is greater than baseline conditions (Scenario A1) but may be artificially elevated owing to the presence of undisturbed clinker and alluvial deposits located in and adjacent

to preserved coulee bottoms. The clinker would probably intercept a significant portion of yearly runoff and recharge coulee alluvial deposits.

North Coulee runoff under Scenario D1 will be impacted to an extent similar to that of Scenario C1. Total acreage disturbed by mining in North Coulee under Scenario D1 is 499 acres; undisturbed lands include 1292 acres. Runoff values total approximately 22.9 AF/year (Table 3). Enhanced runoff under Scenario D1 is likewise subject to the same clinker losses discussed above; thus, the predicted annual runoff value may be artificially high.

3. Interception

Interception losses in the North Coulee drainage are based on a unit interception rate for various vegetation types and on acreage associated with that type. As described in Chapter V, three vegetation types are utilized in this analysis: forest, grassland, and riparian. For each scenario described in Chapter IV, acreages of each vegetation type are multiplied by a unit interception rate, and summed to produce an annual interception volume.

Interception rates for Scenario A1 are based on the following acreages for the vegetation types: forest (575 acres), grassland (1040), and riparian (32 acres). Multiplying individual vegetation acreages by appropriate unit interception rates (Chapter V) and summing yields a total annual interception volume for North Coulee

under Scenario A1 of 375 AF (Table 3). This value represents baseline conditions for the entire North Coulee drainage.

Under Scenario B1, acreages of the three vegetation types are revised to account for the revegetation plan submitted by Westmoreland Resources. As well, total drainage area increases as described previously. Acreages for all vegetation types and both disturbed and undisturbed lands under Scenario B1 include: forest (472 acres), grassland (1287 acres), and riparian (32 acres). Summing the products of these acreages and their corresponding unit interception rates reults in an annual interception volume of 384 AF (Table 3). This value is slightly higher than baseline conditions (Scenario A1) owing primarily to the increase in North Coulee drainage area.

Acreages for vegetation types for both disturbed and undisturbed lands under Scenario C1 include the following: forest (496 acres), grassland (1263 acres), and riparian (32 acres). Utilizing these values and unit interception rates nets a resultant annual interception volume for Scenario C1 of 388 AF (Table 3). This value is slightly more than baseline conditions, again, owing to the increased drainage area.

Interception rates for Scenario D1 are based on factors similar to that for other scenarios. Acreages for combined disturbed and undisturbed areas include: forest (517 acres), grassland (1242 acres), and riparian (32 acres). Based on unit interception rates for the vegetation types, total annual interception volume is 391 AF (Table 3). This value is slightly greater than baseline conditions

(Scenario A1), but this increase is probably due to the increased drainage area reclaimed in North Coulee.

4. Evapotranspiration

Evapotranspiration (ET) volumes for North Coulee are based on factors similar to those described for interception, i.e unit ET rates for individual vegetation types (forest, grassland, and riparian) and acreages associated with each vegetation type. For each scenario described in Chapter IV, acreages of each vegetation type are calculated, multiplied by an associated unit ET rate, and summed to produce an annual ET volume.

Vegetation acreages utilized in the analysis of ET volumes are the same as those calculated for interception. ET rates for the vegetation types are detailed in Chapter V. Table 3 shows the results of these calculations.

ET volumes for Scenarios B1, C1, and D1 are slightly higher than baseline conditions (Scenario A1) for the entire North Coulee drainage (Table 3). This increase is probably due to the expansion of the North Coulee drainage area.

B. North Coulee Above County Road

Evaluations of individual components of the water balance equation (Chapter IV) is completed for the area above the county road (Figure 1) for the various mining alternatives. Special emphasis is placed on evaluating the relative differences of individual components of the right side of the water balance equation (Equation 1), particularily as the scenarios relate to baseline conditions. In this manner, impacts to the hydrologic system of North Coulee above the county road can be quantified and analyzed.

Total pre-mine drainage area above the county road (Figure 1) is 720 acres. The drainage area above the county road increases in size to 864 acres following mining and reclamation. The former is used in evaluating Scenario A2, while the latter is applicable to Scenarios B2, C2, and D2.

As discussed earlier in this chapter, impoundments (Ponds 19 and 20) proposed by WR under Scenario B2 exert a significant impact on several components of the water balance equation. The impoundments recharge alluvial aquifers through pond seepage while simultaneously serving decrease net runoff because of their catchment capabilities.

1. Ground Water

Ground water flow above the county road is impacted by mining activities primarily by the replacement of contributing bedrock and alluvial aquifers with spoils. Impacts are analyzed by comparing

estimated ground water flow under the various mining alternatives to pre-mine baseline conditions.

Total ground water flow at the county road under Scenario A2 is a combination of flows from three aquifers in the area; coulee alluvial deposits, overburden, and the R1 coal. Based on calculations presented in Chapter V, ground water flow for the three aquifers at the county road are as follows: alluvium (2.2 AF/year), overburden (2.1 AF/year), and R1 coal (1.0 AF/year). Total ground water flow at the county road under Scenario A2 is 5.3 AF/year (Table 3). This value is representative of baseline conditions.

Under Scenario B2, spoils replace the overburden and R1 coal entirely above the county road. Based on estimated hydraulic properties for spoils presented in Chapter V and an assumed aquifer width of 6000 feet, annual ground water flow through the spoils under Scenario B2 is 3.9 AF. Seepage loss from the proposed permanent impoundments (Ponds 19 and 20) will recharge alluvial deposits above the county road by approximately 2.2 AF/year. Thus, total ground water flow under Scenario B2 is 6.1 AF/year (Table 3).

Although ground water flow is altered by spoils replacement of bedrock aquifers in Scenario B2, the impact of seepage from the runoff collected in the proposed permanent impoundments more than compensates for this loss, resulting in an annual ground water flow volume comparable to pre-mine conditions (Scenario A2). Therefore, the impoundments may buffer the impact of mining disturbance in upper North Coulee.

Ground water flow under presumptions in Scenario C2 is impacted by replacement of bedrock aquifers with spoils, although the alluvial system above the county road is left intact. Assuming hydraulic properties of spoils outlined in Chapter V and using an approximate spoils aquifer width of 4900 feet, total flow through the spoils aquifer is 3.2 AF/year. Because the coulee alluvial system is undisturbed, ground water flow in the alluvium at the county road is estimated to remain unchanged from Scenario A2 or 2.2 AF/year. Undisturbed bedrock aquifers above the county road contribute 0.7 AF/year to the system. Total annual ground water flow at the county road for Scenario C2 is thus 6.1 AF (Table 3). This value marks a slight increase over baseline conditions (Scenario A2) owing primarily to the increased permeability of the spoils aquifer as compared to existing bedrock aquifers.

Ground water flow under Scenario D2 is impacted in a manner similar to that of Scenario C2. Utilizing spoils hydraulic properties described in Chapter V and an assumed aquifer width of 4900 feet, ground water flow in spoils under Scenario D2 is about 3.2 AF/year. Coulee alluvium is undisturbed in this alternative, and ground water flow is similar to that calculated for Scenario A2 of 2.2 AF/year. An additional 0.7 AF/year is contributed by undisturbed bedrock aquifers above the county road. Total annual ground water flow at the county road under Scenario D2 is 6.1 AF (Table 3). As with Scenario C2, this value represents a slight increase in flow compared to baseline conditions, again, owing to the increased permeability of the spoils aquifer as compared to pre-mine aquifers.

2. Runoff

Surface runoff above the county road is impacted by altered topography and infiltration characteristics resulting from proposed mining under Scenarios B2, C2, and D2. In addition, proposed impoundments in upper North Coulee and an increase in the size of the drainage area above the county road combine to influence total annual runoff at the site under all three mining alternatives.

Utilizing unit runoff rates for undisturbed lands detailed in Chapter V and a pre-mine drainage area above the county road of 720 acres, total annual runoff for Scenario A2 is about 7.2 AF (Table 3). This value represents baseline conditions for North Coulee above the county road.

Runoff under Scenario B2 is impacted by permanent impoundments (Ponds 19 and 20) located near the county road. Because of the design capacity of the impoundments, all runoff under most conditions is contained in the ponds; no runoff occurs at the county road (Table 3). Although no runoff occurs at the county road under Scenario B2, the contained water will provide for alluvial recharge as described earlier, and better provide for riparian habitat.

In Scenario C2, approximately 605 acres of the North Coulee drainage above the county road is disturbed by mining while 259 acres remain undisturbed. Summing the products of acreages and unit runoff rates for both disturbed and undisturbed lands results in a total

annual runoff under Scenario C2 of 14.7 AF (Table 3). This value is nearly double that of baseline conditions owing to the previously noted increase in drainage area and the predominance of disturbed lands under this alternative. Because this scenario provides for maintenance of existing clinker deposits in and adjacent to coulee bottoms, the predicted runoff value may be artificially high owing to the capability of clinker to intercept surface runoff.

Disturbed acreage in North Coulee above the county road under Scenario D2 constitutes 499 acres while undisturbed lands include 365 acres. Using unit runoff rates and appropriate acreages for both disturbed and undisturbed lands results in a total annual runoff under Scenario D2 of 13.6 AF (Table 3). This value is probably high due to reasons outlined for Scenario C2 above.

3. Interception

Total interception volume for each mining alternative is based on acreage of individual vegetation types present in the North Coulee drainage above the county road and on unit interception rates for the vegetation types. Vegetation types evaluated in this analysis include forest, grasslands, and riparian. The total acreage for each vegetation type is dependent on revegetation plans submitted by Westmoreland for the various mining alternatives, or upon pro-rated acreages determined from the same plan. Unit interception rates for the vegetation types are those described in Chapter V.

Vegetation types and acreages in Scenario A2 include the following: Forest (263 acres), grasslands (443 acres), and riparian (14 acres). Utilizing appropriate unit interception rates and summing the three vegetation types results in a total annual interception volume under Scenario A2 of 166 AF (Table 3). This value represents baseline interception conditions for North Coulee above the county road.

Interception characteristics for Scenario B2 are based on the following vegetation acreages: forest (160 acres), grasslands (690 acres), and riparian (14 acres). These acreages constitute combined disturbed and undisturbed lands, as well as the increased size of the North Coulee drainage area above the county road. Multiplying the acreages by their corresponding unit interception rates (Chapter V) and summing the results indicates a value slightly greater than baseline conditions, owing primarily to the increase in drainage area.

Under Scenario C2, interception volume is based on the same unit intercepiton rates and on the following acreages for vegetation types: forest (184 acres), grasslands (666 acres), and riparian (14 acres). Total interception volume for Scenario C2 is 179 AF/year (Table 3). The slight increase in this value over baseline conditions (Scenario A2) is again primarily due to the increase in draiange area of North Coulee above the county road.

Vegetation type acreages for Scenario D2 include the following: forest (205 acres), grasslands (645 acres), and riparian (14 acres).

These acreages represent the sum of both disturbed and undisturbed lands above the county road for this mining alternative. The total interception volume for Scenario D2 is 182 AF (Table 3). The slight increase in this value as compared to baseline conditions (Scenario A2) is due to the same factors outlined for Scenarios B2 and C2.

4. Evapotranspiration

Evapotranspiration (ET) for North Coulee above the county road is based on the same vegetation acreages for each mining alternative as is used for interception, and on unit ET rates identified in Chapter V.

Evapotranspiration values for Scenarios B2, C2, and D2 are elevated slightly as compared to baseline conditions (Scenario A2, Table 3). Elevated ET losses are primarily due to the increased drainage area of North Coulee above the county road.

VII. CONCLUSIONS AND SUMMARY

The results of this water balance investigation of four land use scenarios for North Coulee are summarized in Table 3. In all cases the sum of hydrologic system outputs exceed estimated system inputs by approximately 25 percent. This difference does not render the exercise useless; in fact, the difference is actually reasonably small for this type of an investigation. Moreover, because the same methods are used to calculate system losses (the rigth side of Equation 1) consistently throughout all scenarios, the results are considered to be a reasonable approximation of North Coulee's system response to such land use alternatives.

The most important observations to be made from Table 3 are based upon comparisons of runoff and ground water flow among the various scenarios. Predicted changes in interception and evapotranspiration losses do not vary significantly in any case, but in all cases they comprise more than 98 percent of calculated water uses in the coulee. It seems ironic that so much attention is given surface and ground water occurrence in North Coulee when together they constitute so little water consumption.

Ground water discharge from or into North Coulee does not change significantly under any scenario (Table 3). Absolute changes in the predicted values should not be construed to represent "real" measurements, however. The most that should be interpreted from these values is that pre-mining and post-mining ground water movement in North Coulee would be comparable. Much of this conclusion rest.

the accuracy of the assumption that the post-mining ground water flow system in upper North Coulee will be locally recharged, approximate the surface watershed in shape and size, and discharge toward the adjacent, undisturbed lower portion of North Coulee. In the absence of any known external factors which would affect post-mining ground water flow, this is reasonable. Based upon available data, it is likewise reasonable to assume that spoils will be at least as transmissive as the pre-mining bedrock units.

It should also be stated that these assumptions are predicated upon an equilibrium post-mining hydrologic system, which will certainly require tens to hundreds of years to establish itself. Until the spoils are saturated, post-mining ground water movement in the spoils discharging to North Coulee may approach zero.

Comparability of ground water flow volumes between scenarios is not the same as predicting that all springs left undisturbed under Scenarios C and D would discharge unabated if mining were to occur. This type of water balance analysis is not applicable to such site-specific predictions.

Runoff changes significantly among the scenarios (Table 3), primarily in response to three factors: construction of two permanent impoundments under Scenario B, which markedly decreases runoff to the lower coulee and to East Fork Sarpy Creek; an increase in the watershed size as a result of mining under any scenario; and the compensating influences of possible increased runoff rates for

disturbed surfaces and lower runoff rates where near-surface clinker is the parent material of soils. The former allows for decreased runoff from North Coulee under Scenario B, while the latter factors induce greater predicted runoff volumes.

All predictions are closely dependent upon the assumption of revegetation success following mining. Given the current status of revegetation on mined lands in southeastern Montana, this assumption is reasonable. As long as some permanent vegetative cover is established, the relative importance of interception and evapotranspiration losses within North Coulee would not change significantly.

In summary, it is concluded that all mining scenarios evaluated in this investigation would result, after hundreds of years, in a hydrologic system comparable to that which existed prior to mining. Specific springs may be mined out, change discharge rates, or dry up completely, under mining Scenarios B, C, or D, but the ultimate water balance within North Coulee would probably not change. The two most critical assumptions to this conclusion are the reestablishment of a locally recharged ground water basin in reclaimed upper North Coulee, and ultimate success of revegetation on mined lands.

The major difference between pre-mining conditions (Scenario A) and the proposed mine plan (Scenario B) is that the mining alternative should decrease runoff and increase alluvial ground water recharge below the mine area. This may actually result in enhanced spring flow below the impoundments.

VIII. REFERENCES CITED

Crouse, R. P., Corbet, E.S., and D.W. Seegrist, 1966, Methods of Measuring and Analyzing Rainfall Interception by Grass. International Association of Scientific Hydrology Bulletin, Vol. 11, No. 2, pp. 110-120.

Dunne, T. and L.B. Leopold, 1978, Water in Environmental Planning. W.H. Freeman and Company. San Francisco.

Envirosphere Company, 1979, Potential Impacts on Hydrology, Vegetation and Wildlife in the Immediate Vicinity of Proposed Five-Year Mine Development, Absaloka Mine, Big Horn County, Montana. Report prepared for Westmoreland Resources, Inc.

Hydrometrics, 1979, Hydrologic Impact Reports, prepared for Westmoreland Resources, Inc., August, October.

Leaf, C.F., 1979, Hydrologic Impacts of Strip Mining on Tract III - East Fork Sarpy Creek. Report prepared for Westmoreland Resources, Inc.

Montana Department of State Lands and United States Department of the Interior, Office of Surface Mining, 1984, Draft Environmental Impact Statement: Westmoreland Resources' Absaloka Mine, Revised Plan, Big Horn County, Montana.

NOAA, 1984, Climatological Data: Montana Annual Summary. National Oceanic and Atmosphere Administration, U.S. Department of Commerce.

Rahn, P.H., 1976, Potential of Coal Strip-Mine Spoils as Aquifers in the Powder River Basin. Report for Old West Regional Commission, Project No. 10470025.

Stiller and Associates, 1984, Analysis of Proposed Post-Mining Surface Water Storage Impoundments at Westmoreland Resources Absaloka Mine. Technical Support Document for the Absaloka Mine DES.

Stiller, David, 1979, Letter to Brace Hayden, Montana Department of State Lands, July.

U.S. Geological Survey, 1983, Water Resources Data for Montana, USGS Water-Data Report MT-83.

Westmoreland Resources Inc., 1983, Absaloka Mine permit application. 12 volumes. Hardin, Montana.